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Enhanced Gain of Dual Band Microstrip Antenna Using Reflector for RF Energy Harvesting Applications

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Abstract : *Research efforts to collect RF energy in the environment have gained momentum since the late 1990s. The RF harvesting is the process in which the RF power that is widespread in the environment or that radiates a specific source, is grounded by a receiving antenna with suitable circuits, and turned into a DC power. In this letter, design of a dual-band microstrip patch antenna is introduced for RF energy harvesting applications is aimed. Firstly a microstrip design is achieved in 3D simulator environment and then by adding a reflector to the design the performance of the design had been enhanced. The simulated and experimental results of the proposed antenna design is compared and the results suggested that the proposed design is suitable for RF harvesting applications.*

Keywords: *RF energy harvesting, Antenna Design, Dual band, GSM band, ISM band*

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I. Introduction

RF Energy Harvesting systems convert the electromagnetic energy in the environment into analogue signal by interacting with an antenna which is at the effective radiation aperture of the electromagnetic waves in the air. RF Energy Harvesting circuits convert the electromagnetic energy in the environment, as it is given in table 1, into analogue signal by interacting with an antenna which is at the effective radiation aperture of the electromagnetic waves in the air. The collected energy is transmitted in amplifiers and rectifier circuits, harvesting systems of micro-energies are used in many applications such as remote sensing, calculator, clock, Bluetooth, headphones and wireless sensors. These harvesting technologies can be listed as vibration, light, temperature difference and RF Emissions [1]. The harvested energy allows the battery life to be extended on mobile phones. RFID systems can be fed by this technique in emergency situations when electricity is cut off or when batteries are depleted.

Table 1. RF Energy Sources Frequency Bands [1].

RF Power Generator Resources	Frequencies (MHz)
FM	87.5 - 108
Radio	370 - 450
UHF	470 - 854
VHF	174 - 230
GSM900	935 – 960
GSM1800	1805 – 1880
Wi Fi	2400 - 2483.5
3G	2110 – 2200
Wi-MAX	2500 - 2690 and 3400 – 3600

Research efforts to collect RF energy in the environment have gained momentum since the late 1990s. This acceleration is mainly due to the growth of low power RF transmitter devices and the electronics is widespread. Hagerty [2] presented a broadband array of antennas that harvested ambient RF power over the 2-18 GHz frequency range from previous work. Also, in 2009, Intel Research Seattle, TV station showed a 960 kW 4.1 km from the RF energy is harvested using flour [3]. Powercast a smaller power by performing a similar study in 2005 (5 kW AM) radio station [4] were harvested 2.4 km away from successfully using the RF energy. The RF Power, which is widespread in the environment or that radiates a specific source, is grounded by a receiving antenna with suitable circuits, and turned into a DC power, and the converted DC power can be used with the help of impedance matching, filter and voltage boosting, current pumps [1]. This technology, which plays an important role in the feedings of especially low-power integrators, can be extensively examined with advantages and disadvantages by making some comparisons between other energy conversion systems. Radio Frequency (RF) energy, especially available in environments such as Wi-Fi networks and mobile stations. In this case, RF energy which the mobile station may broadcast harvested at different frequencies. For example, wireless modem transmitters at short distances can transmit power from 50 to 100 mW.

In order to have a high efficiency conversion rate in RF harvesting system, a high performance antenna design is required. In the next section, a dual band antenna design with high performance criteria's for RF energy harvesting applications had been studied. Alongside of the simulation results the experimental results of the manufactured antenna had been studied.

II. Dual Band Antenna Design

In this section the design procedure of a high gain dual band antenna for RF energy harvesting unit is presented. One of the most important parameters affecting the efficiency of a RF energy harvesting unit is an antenna with high gain characteristic alongside of small size and low fabrication cost. For this mean microstrip antenna designs had been chosen as the optimal antenna model due to their high interested in recent years and their ability of achieving high performance results in small size with low cost [5-7].

For achieving this criteria, an antenna consists of two microstrip monopoles with different lengths is placed in the top layer of the dielectric substrate FR4. The monopoles have a common feeding via a microstrip line with a tuning stub. The schematic and design parameters of the antenna are given in Fig. 1 and table 2. The geometrical parameters given in table 2 are chosen as the optimal values for the selected operation frequencies.

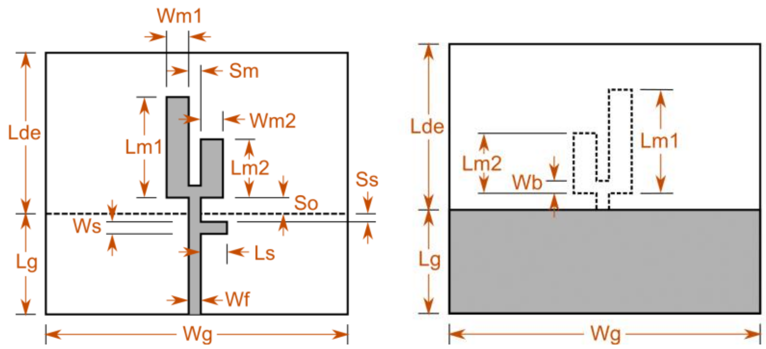


Fig. 1 Schematic of the Proposed Dual Band Antenna

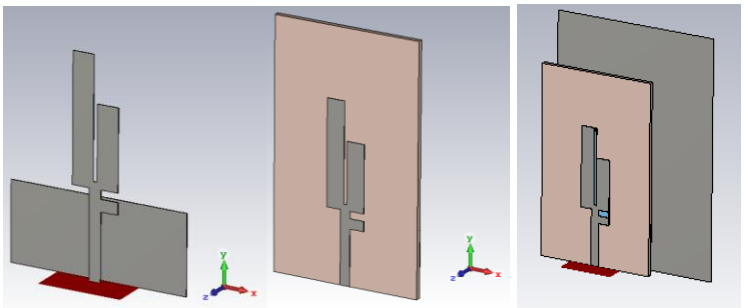
Table 2. Antenna Parameters in (mm)

Ss	0.2	***Sm***	0.94
Wm1	5.36	***Lm1***	31.99
Wm2	5.36	***Lm2***	30.33
Wg	45	***Ls***	4.36
Wf	3	***Lg***	22.5
Ws	3	***Lde***	53.36

As it mentioned, the dual band operation of this antenna is achieved by having two monopole elements of different lengths. The difference in lengths produces two different current paths and results in a dual-resonance mode of operation. The longer monopole element is responsible for the lower band of operation whilst the shorter monopole element the upper band of operation. In other word:

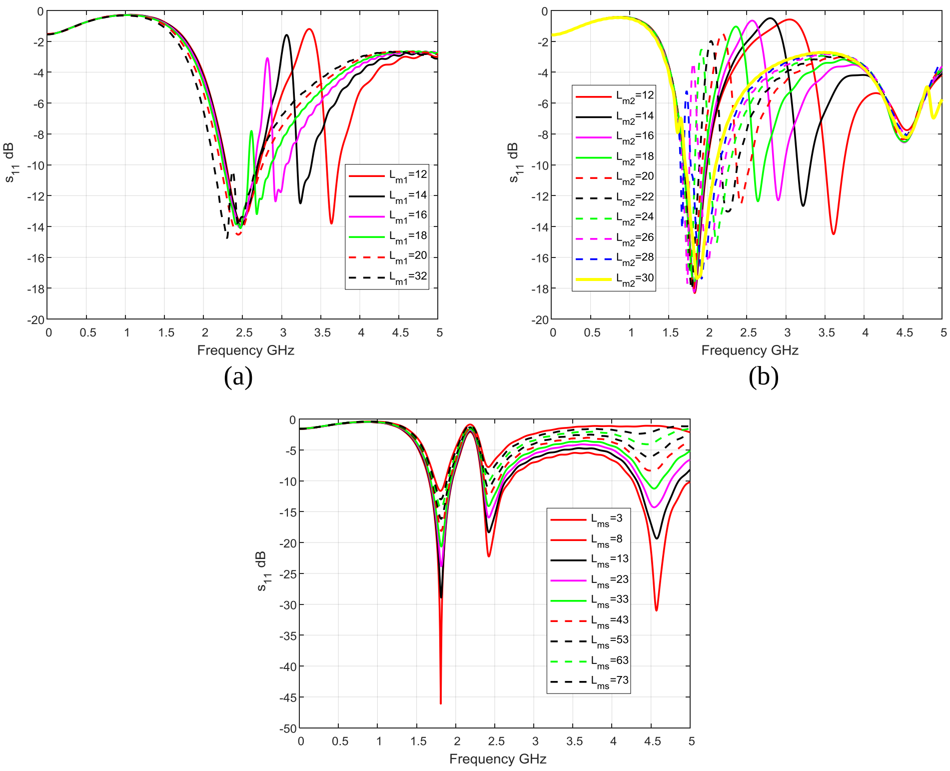
- The lower operating frequency may be increased (decreased) by decreasing (increasing) the Lm1.
- The upper operating frequency may be increased (decreased) by decreasing (increasing) the Lm2.

The length of the tuning stub was found to be very effective in controlling the coupling of the electromagnetic energy from the microstrip feed line to the strip monopole antenna, while maintaining a good impedance match in the two bands of operation [9-10]. Furthermore, a reflector design had been added to the model in order to further increase the gain performance of the antenna. In Figures 2-5 and table 3, the 3-D model of the antenna designs had been given alongside of their simulation results with respect to the geometrical design parameters.



(a) (b)

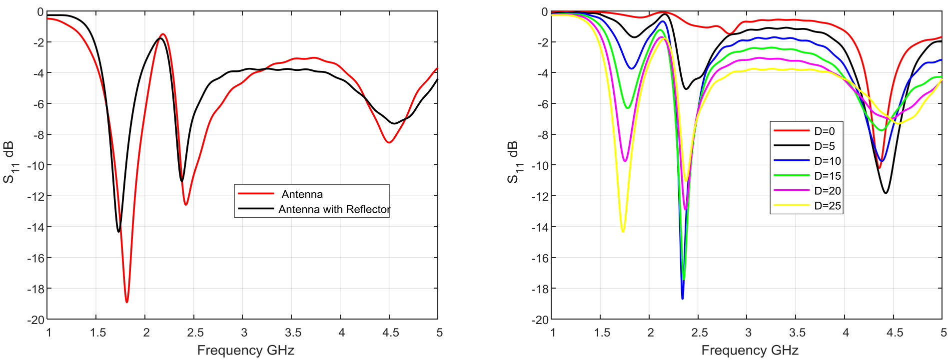
Fig. 2 3-D view of Antenna Geometry (a) without, (b) with Reflector.



(a) (b)

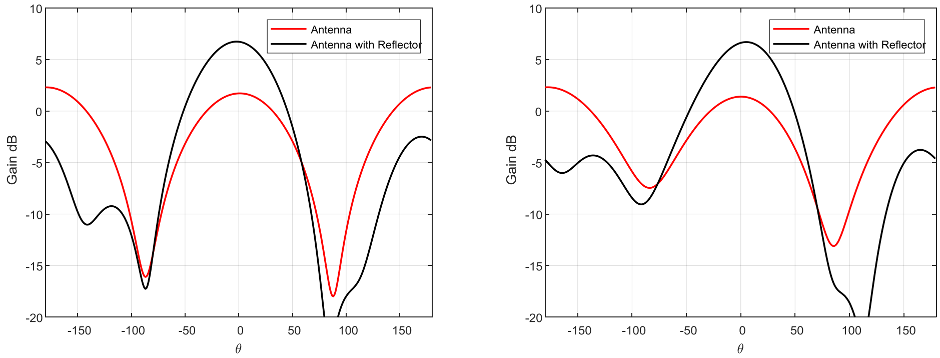
(c)

Fig. 3 Simulated Variation of (a) Lm1, (b) Lm2, (c) Ls length on S_{11}



(a) (b)

Fig. 4 Variation effect of (a) A Reflector, (b) Distance of Reflector, to the S_{11} Performance of the Antenna Design



(a) (b)

Fig. 5 Simulated Gain Performance of the Antenna @ (a) 1.8GHz, (b) 2.4GHz.

Table 3. Simulated Performance Results of the Antenna

Antenna	Frequency (MHz)	S_{11} dB	Max Gain dB
Without Reflector	1800	-19	2.3
	2400	-13	2.32
With Reflector	1800	-14.3	6.73
	2400	-11	6.7

III. Experimental Results

In this section the experimental results of the simulated antenna in section 2 is studied. The prototype antenna and measurement setup are given in figures 6-7 respectively. The maximum far field gain of the proposed antenna is measured using the measurement setup shown in Fig. 7, by using two identical antennas given in [10].

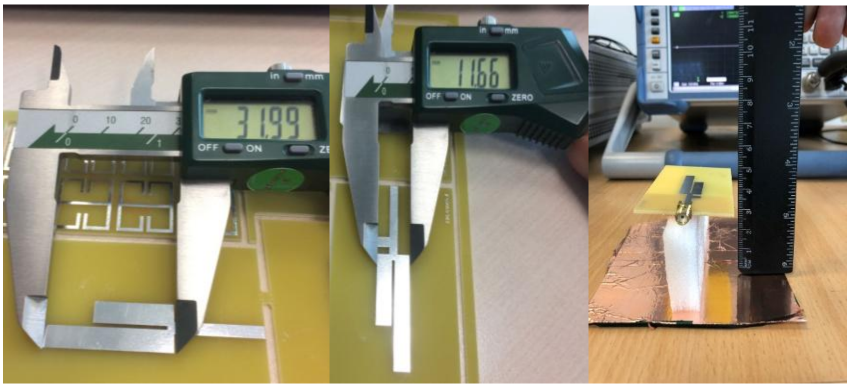
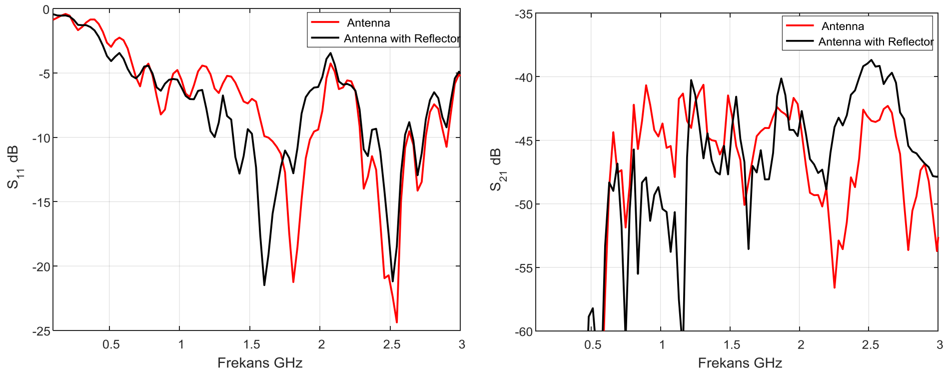


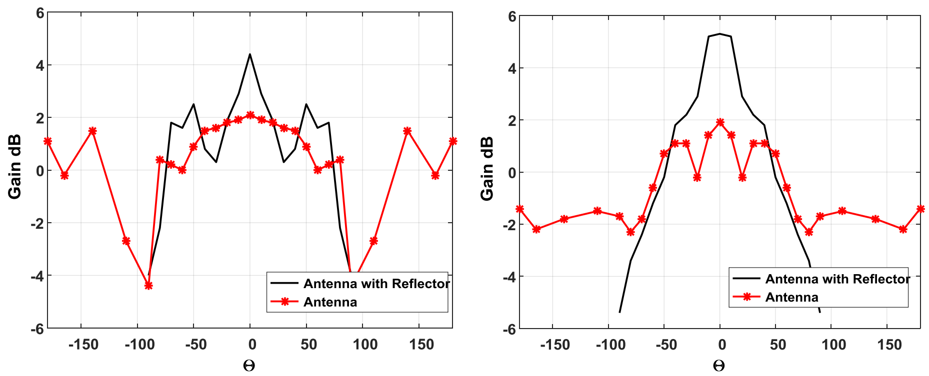
Fig. 6 The Prototyped Antenna Model

Fig. 7 Measurement Setup for Maximum Far Field Gain.



(a) (b)

Fig. 8 Measured (a) S_{11}, (b) S_{21}, Characteristics of Antenna Designs



(a) (b)

Fig. 9 Measured Gain Performance of the Antenna @ (a) 1.8GHz, (b) 2.4GHz.

IV. Conclusion

Herein, a dual-band high gain antenna design for energy harvesting application has been achieved. The antenna design operates 1.8 and 2.4 GHz which is a highly effective band for RF energy harvesting applications. As it can be observed from the measurement results the proposed antenna design with a reflector has a high gain performance characteristics in the selected operation band. The measurement suggested that the design is an optimal model for RF energy harvesting applications. The measured results showed the gain of 5 and 7 dB at 1.8 and 2.4 GHz, respectively. A good agreement is found between the simulated and measured results for reflection coefficient in addition to radiation characteristics.

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